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Gilbert Bay Marine Protected Area science indicator monitoring

Surveillance des indicateurs scientifiques de la zone de protection marine de la baie Gilbert

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ABSTRACT

Gilbert Bay, Labrador has been closed to commercial fishing for Atlantic cod (*Gadus morhua*) since 1999, and since 2005 it has been a Marine Protected Area (MPA) under Canada's Fisheries Act and Oceans Act, specifically to protect the genetically distinctive population of Atlantic cod. Demographic characteristics of the cod population and the movement patterns of individual fish have been studied continuously since 1998. Here we describe data used to derive 5 indicators of population change: 1. recruitment of age 0 pelagic juveniles, 2. recruitment of ages 2, 3, and 4 year old fish, 3. research catch per unit effort, 4. movement and migration patterns and 5. catch data from commercial, sentinel, aboriginal, and food fishing. In recent years there has been a low abundance of age-0 pelagic juveniles. Fish comprising relatively strong cohorts have grown in size under protective regulations but recruitment of cod ages 2, 3 and 4 years has been highly variable. Research catch per unit effort has declined, indicating a decline in both numbers and biomass. Tagging and tracking data from external tags and implanted sonic transmitters show that fish < 40 cm generally exhibit high site fidelity while an unknown proportion of larger fish migrate to the outer parts of the Bay, which can include areas well outside the MPA boundaries. Concurrent with the decline, there has been an increase in fishing effort and amount of fish caught in areas adjacent to the MPA

Key-words: Marine Protected Area, Atlantic cod, recruitment, population demographics, Newfoundland and Labrador.

RÉSUMÉ

En 1999, on a interdit la pêche commerciale à la morue (*Gadus morhua*) dans la baie Gilbert, au Labrador. Depuis 2005, la baie est désignée en tant que zone de protection marine (ZPM) en vertu de la *Loi sur les pêches* et de la *Loi sur les océans* fédérales, notamment afin de protéger la population de morues génétiquement distincte qui y vit. Les caractéristiques démographiques de la population de morues et les profils de déplacement des individus de l'espèce sont étudiés depuis 1998. Le présent document décrit les données que l'on a utilisées pour établir 5 indicateurs de changement dans la population : 1) recrutement des juvéniles pélagiques d'âge 0; 2) recrutement des individus d'âge 2, 3 et 4; 3) prises par unité d'effort de la pêche scientifique; 4) profils de déplacement et habitudes migratoires; 5) données sur les prises provenant des pêches commerciales, sentinelles, autochtones et alimentaires. Ces dernières années, l'abondance des juvéniles pélagiques d'âge 0 est demeurée faible. Les poissons des cohortes relativement abondantes ont grossi au cours de la période de protection couverte par la réglementation, mais le recrutement des morues d'âge 2, 3 et 4 varie fortement. Les prises par unité d'effort de la pêche scientifique ont décliné, ce qui indique un déclin de l'effectif et de la biomasse. Les données d'expériences de marquage et de suivi recueillies à l'aide d'étiquettes externes et d'émetteurs acoustiques implantés indiquent que les poissons de moins de 40 cm affichent d'ordinaire une grande fidélité au site, mais une proportion inconnue de plus grands poissons migrent vers les parties extérieures de la baie, ce qui peut comprendre des zones bien à l'extérieur des limites de la ZPM. Parallèlement au déclin, on a observé une augmentation de l'effort de pêche et de la quantité de poissons capturés dans les zones adjacentes à la ZPM.

Mots-clés : zone de protection marine, morue, recrutement, caractéristiques démographiques, Terre-Neuve et Labrador.

INTRODUCTION

Gilbert Bay is located on the southern coast of Labrador (Figure 1). A process to establish it as a Marine Protected Area (MPA) began in 1998, and the area was formally designated in 2005 (Canada Gazette, 2005). The regulatory intent of the Gilbert Bay MPA is to protect and conserve a population of Atlantic cod which reside in Gilbert Bay, and its habitat (Canada Gazette 2005). Our MPA research on the Gilbert Bay cod population started in 1998, initially conducted by Memorial University researchers, and has continued until present as a collaborative research and monitoring project between Memorial University and the Department of Fisheries and Oceans Canada. Additional research collaborations have also included the Labrador Métis Nation in recent years.

Since 1998 our sampling has found that the primary overwintering and spawning site in Gilbert Bay has been The Shinneys, a small semi-enclosed area within the Bay. Spring catch rates of spawning cod in The Shinneys has been 7 to 9 times greater than other sampling areas in Gilbert Bay (Morris et al 2003). As a result, spatial coverage of hook and line sampling has focused on The Shinneys, so as to most effectively utilize time and personal. The timing of spawning appears to be related to the time of spring thaw and is concurrent with when some cod begin to migrate from The Shinneys. Spring sampling is therefore conducted during the spawning period and just prior to the movement of cod to outer parts of the bay.

We present research and monitoring data in terms of 5 indicators, used here to describe trends reflecting changes in the Gilbert Bay cod population. These are:

1. Recruitment of age 0 pelagic juveniles
2. Recruitment of ages 2, 3, and 4 year old Atlantic cod
3. Research Catch Per Unit Effort
4. Movement and migration patterns
5. Catch information from commercial and other fishing activities

These indicators provide information for peer review and scientific assessment of potential changes in the Gilbert Bay cod population. Scientific advice can potentially assist MPA managers to determine if the Gilbert Bay MPA is effective in reaching its conservation objectives.

METHODS

ANNUAL SAMPLING

Each year at least two trips are made to Gilbert Bay to conduct MPA research and monitoring (Table 1). Each trip is approximately 1-2 weeks in duration; the first is conducted during spring (late May to early June) and the second during summer (early August). Monitoring work is conducted from small boats, between 4 and 7 m in length. Spring monitoring occurs during the Gilbert Bay cod spawning season at which time Gilbert Bay cod are concentrated at overwintering locations (Morris and Green 2002). Summer monitoring occurs when fish are more dispersed (particularly adults) from their overwintering areas (Green and Wroblewski 2000), and age 0 Atlantic cod are pelagic.

ICHTHYOPLANKTON SAMPLING

Indicator 1, recruitment of age 0 pelagic juveniles, is based on ichthyoplankton sampling. Sampling is conducted with a 1 meter diameter ring net with 333 micrometer mesh, towed horizontally through the water column for 15 minutes. Atlantic cod egg samples are collected at depths of 2 m (surface sample), 5 m (near the picnocline) and 8 m (bellow the picnocline) during spring sampling. Age 0 pelagic juvenile Atlantic cod are collected during summer ichthyoplankton sampling, and consists of only surface (< 2m) sampling. Approximately 10-30 Ichthyoplankton samples are collected from the same areas of Gilbert Bay each sampling period, primarily in The Shinneys. Samples are preserved in formalin and /or ethanol for analysis.

RESEARCH CATCH DATA

Hook and line sampling, conducted since 1998, is the preferred means of sampling Atlantic cod in Gilbert Bay. Hook and line sampling catches nearly all sizes of Atlantic cod (fish greater than 15 cm) in Gilbert Bay and does not adversely impact bottom habitats. Sampling is conducted at approximately 28 regular sampling sites distributed throughout inner-Gilbert Bay (Figure 2), and several other locations in the bay that are sampled less regularly. The time, duration, and number of people fishing at each location are recorded. In general, sampling at each site consists of a minimum of 30 minutes and rarely exceeds 120 minutes consecutively, and sites are not fished sequentially. Upon capture each cod is measured for total length (TL) to the nearest millimeter and examined. Examination includes gently squeezing the abdomen to check for sexual maturity (identified by the presence of eggs or milt), the gills are examined for parasites, and any net marks are noted. Healthy fish larger than 30 cm are marked with an external individually numbered tag and released at the location of capture. Recaptured cod, fish with an external tag from previous tagging, are sacrificed; however, recaptures per trip rarely exceed 20. Sacrificed fish are measured, sometimes weighted (depending on sea conditions), otoliths are removed, stomach contents identified and gut fullness is estimated. Data from recaptured fish provide an indication of fish movements, growth rates, feeding, and abundance.

Indicator 2, recruitment of ages 2, 3 and 4 year old Atlantic cod, is based on relative juvenile year class strengths. Juvenile year classes are identified based on examination of modes in length frequency distributions. Because few otolith samples are collected each year, relative abundance of year classes based on otolith samples is not possible. However, existing age-length keys can be used to estimate year classes (Figure 3). Based on these data, modes in the length distribution are assigned ages up to approximately 4 yrs, after which modal analysis is difficult due to highly variable growth rates, likely with the onset of sexual maturation.

Indicator 3, research catch per unit effort, is based on sampling rate over time. Research catch per unit effort (CPUE) is calculated as the number of fish caught divided by the number of people fishing multiplied by the time (hrs) each person spent fishing. The annual seasonal catch is standardized to the average seasonal sampling effort during the 11 year time series, (i.e. annual mean effort of 178 hours of fishing each spring). Throughout the entire time series, 1998-2009, research catch rates are determined by trip (no error estimate) and by the mean daily catch rates (+/- standard error). Since 2005, the mean catch rate per site is calculated (+/- standard error). Specific effort information for each sampling site was not consistently recorded until 2005.

Indicator 4, movement patterns, is based on tagging and recapture of Gilbert Bay cod sampled by hook and line. Further inferences are based on length frequency distributions between May and August.

Data for indicator 5, catch information from commercial and other fishing activities, is based on DFO landings data and tag returns from various sources of fishing effort. Tag returns provide recapture locations which delimit the area within which fishing could potentially encounter Gilbert Bay cod. Tag returns come from commercial, recreational, sentinel, and aboriginal fishing outside the MPA.

RESULTS

INDICATOR 1: RECRUITMENT OF AGE 0 PELAGIC JUVENILES

Ichthyoplankton samples collected in late May and early June indicate that the majority of Atlantic cod eggs sampled in The Shinneys are at the same early stage of development (Morris and Green 2002). Vertically the highest concentration of cod eggs in the Shinneys occurs at the interface between the low density surface water layer resulting from spring runoff and more saline deeper water. Ichthyoplankton sampling conducted 45-55 days later during the first week of August, has collected pelagic juvenile cod only. In addition, no female cod have been observed in spawning condition in early August, indicating that spawning occurs over a contracted and specific time period in May and June. Pelagic fish caught in August generally range in size from 20-35 mm total length (TL).

Average annual densities of pelagic juvenile cod have ranged from 0.2 – 7.0 cod per tow (Figure 4). Densities are higher at dusk than during the day. Although the abundance of pelagic juveniles is our earliest indication of year class strength, comparisons of catches with hook and line data has produced weak correlations.

INDICATOR 2: RECRUITMENT OF AGES 2, 3, AND 4 YEAR OLD ATLANTIC COD

Since the Gilbert Bay monitoring program began in 1998, annual length frequency distributions describe important trends in population demographics. Modes representative of demersal juvenile cohorts are consistent and predictive over multiple consecutive years of data. Length frequency distributions presented in Figures 5 and 6 depict the relative abundance and size distributions of fish sampled during spring and summer sampling. Figure 7 indicates recruitment of Atlantic cod ages 2, 3 and 4, represented by modes between 16-19, 20-25 cm and 25-30 cm TL respectively. Cod between 16 and 19 cm TL (age 2 yr) in 1998 were relatively abundant. This 1996 cohort was sampled during several consecutive years as represented by fish at ages 2-5 in consecutive years. In 2002 the 1996 cohort probably represented a large number of fish 35 to 40 cm in length. The 1997 cohort however was comparatively weak as indicated by few fish between 16 and 19 cm TL in 1999, and a continued absence of this year class from several subsequent annual length frequency distributions was evident. The strongest cohorts produced since 1996 were in 2000, 2001, and 2006. The number of 2 year olds caught in 2008 and 3 year olds in 2009 suggests that the 2006 year class is relatively strong.

INDICATOR 3: RESEARCH CATCH RATE

CPUE data from research fishing are presented in figure 8. The highest catch rates occurred in 1998, after 6 years of the northern cod fishing moratorium. Catch rates have been lower since then. The biomass of Gilbert Bay cod sampled has also decreased, but has been particularly low during the last two years, because very few large fish were caught during research sampling. Overall, the decrease in research CPUE and biomass is inversely related to the commercial catch data (Figure 9).

INDICATOR 4: MOVEMENT PATTERNS

In recent years recapture of tagged cod has continued to provide valuable data on movements and in the past was also useful in estimating population size (Morris et al 2003). Since 1998 we have recaptured 266 tagged cod during spring and summer research sampling (Table 3). Recaptures indicate that fish are very site specific or exhibit homing behaviour, with fish usually being recaptured within a few hundred meters of their initial tagging location regardless of the length of time since tagging. A number of tagged Gilbert Bay cod (103) have been recaptured by commercial and recreational fisherman outside the MPA during summer and fall, indicating that some large cod move outside of the MPA at this time of year. Reporting rates from fishers are unknown, so recaptures in relation to commercial catch rates have not been a useful indicator of population size. The location of cod recaptured during commercial fishing activity, which were initially tagged in The Shinneys during spring, has indicated that many Gilbert Bay cod move outside the MPA boundaries. In general, cod which were tagged in The Shinneys have been caught in neighboring Alexis Bay, and along the head lands which are approximately 20 km from The Shinneys. Some fish have been caught at least 10 km North and 30 km South along the coastal headlands adjacent entrances to Gilbert Bay.

Figure 10 (as well as Figure 5 and 6) indicates that all year classes are sampled in The Shinneys during both spring and summer, but during summer a large portion of fish larger than 40 cm are absent from The Shinneys. Acoustic tagging and tracking (Morris et al 2009; Morris and Green unpublished data; Green and Wroblewski 2000) confirm that an unknown, but large, proportion of larger cod start to move out of the Shinneys in late May and early June.

INDICATOR 5: COMMERCIAL AND OTHER FISHING

The size of 105 tagged fish that were recaptured during commercial fishing from 1998 to 2008 is shown in Figure 11. During 1998 and 1999 commercial fishing was conducted inside Gilbert Bay, prior to MPA regulations. Since 1999 commercial fishing in Gilbert Bay has been prohibited, however tagged cod have been caught in areas outside Gilbert Bay, most of which were larger than 45 cm TL.

Available information indicates that fishing in Gilbert Bay, and outside Gilbert Bay, reduced Gilbert Bay cod abundance. When fishing was stopped (both inside and outside the MPA) there were increases in abundance or biomass. The population structure observed in 1998 indicates strong recruitment during the 6 year fishing moratorium, based on the abundance of fish between 35 and 45 cm TL in 1998. A sharp decline in the number of fish greater than 55 cm is also observed in the 1998 length frequency distribution (Figure 5). Many fish greater than 55 cm in 1998 could have been caught

during commercial harvesting prior to the 1992 northern cod moratorium, based on length at age data (Morris and Green 2002), when commercial fishing was conduced within Gilbert Bay (Powell 1987). Since 1998, a comparison of our data with reported landings (Table 3) indicates a negative correlation between year of commercial fishing and change in CPUE between sampling years (Figure 9). There also appears to be some increase in research catches during years of no fishing. Landings have increased in the vicinity of Gilbert Bay during the past three years (Table 3), research catch rates of fish larger than 45 cm (commercial size) has also decreased considerably during 2008 and 2009 (Figure 5), which is reflected in a similar drop in biomass sampled (Figure 8, lower panel).

DISCUSSION

The data and associated indicators presented reflect population trends. Future application of these data should include development of a decision-making framework incorporating the precautionary approach, in the form of reference points and control rules to guide future management decisions.

To date, our density estimates of age-0 pelagic juvenile cod has not been a consistent indicator of cohort abundance. It is not surprising to identify high annual variability and lack of correlation when comparing the abundance of age-0 pelagic juveniles with older year classes, likely as a result of high and unpredictable natural mortality at this life history stage. A similar lack of correlation was identified by Gregory et al (2007) when comparing the abundance of age-0 cod with the abundance of age-1 cod and older year classes sampled along the north east coast of Newfoundland. However, sampling age 0 fish does contribute important information which may improve our understanding of juvenile cod mortality, such as the effects of temperature, spawning and settlement time, and feeding environment. Understanding the relationship of these and other potential variables, in relation to juvenile density is an important part of understanding cod population dynamics.

Catches of demersal juvenile cod (ages 2, 3 and 4 years) provide valuable information regarding the demographic features of the Gilbert Bay cod population. Cod are demersal juveniles from the time they settle to a demersal life history, during the first season of life, until they reach sexual maturity; Gilbert Bay cod start to mature at age 5 (Morris and Green 2002). Prior to sexual maturity, the growth pattern of year classes is more consistent among individuals, and length frequency distributions can be used to identify juvenile cohorts. However, modal analysis in this situation is not without problems. Research gear selectivity appears to be most variable for 2 yr old cod, the smallest size of fish caught by our hook and line sampling. For example, the number of age 2 cod sampled in Gilbert Bay is consistently lower than the number of age 3 cod sampled. The absence of 2 yr olds during sampling in 2000 and their presence as 3 year olds in 2003 illustrates the problem. However, in most instances strong year classes were detected first at age 2. When year classes are detected, even at age 2 their presence as a cohort can usually be followed until at least age 4 or 5. As fish get older, individual growth rates change and length at age becomes increasingly variable. This results in a considerable overlap of cohort modes at about age 5. More detailed information on year class strengths will require increased lethal sampling and the determination of age from analysis of otoliths. Lethal sampling, particularly of large cod, has been a very limited part of the Gilbert Bay monitoring program for conservation reasons, and monitoring

work has not attempted to resolve year class abundance trends for all cohorts on an annual basis. Therefore, trends in the abundance of mature cod that are of commercial size are based on a general interpretation of length frequency distributions and catch per unit effort data.

Several acoustic tagging and tracking studies were conducted since 1998 that have investigated the movement patterns of cod in Gilbert Bay. Size specific behavior, seasonal migration patterns, and foraging movements to areas adjacent to Gilbert Bay have been documented. Over the past three years MUN and DFO researchers have established a network of data logging receivers covering much of Gilbert Bay to collect information on movement throughout the year. These data will provide better information on the timing of migration and habitat use both within and outside the MPA.

The Gilbert Bay MPA has undoubtedly protected the local Atlantic cod population, and is successful in delivering its regulatory mandate of cod conservation. From the 1970's until 1992, commercial fishing was conducted within Gilbert Bay (Powell 1987; Morris et al 2002b), and presumably reduced the abundance of the Gilbert Bay cod. The 1998 length frequency distribution and relatively high catch rates suggests that some population rebuilding occurred between 1992 and 1998, during the northern cod moratorium. Commercial fishing directly within Gilbert Bay resumed in 1998 and 1999 and resulted in a decrease of our research catch rates. During 1998, approximately 18 tons of Gilbert Bay cod were harvested and a further 16 tons in 1999, which represented as much as a third of the estimated population size (Morris et al 2003). It is likely that continued fishing at this intensity directly within Gilbert Bay, with the observed level of recruitment in recent years, would have resulted in decimation of the Gilbert Bay cod population, perhaps within 4 to 6 years. Fishing restrictions in Gilbert Bay (using a fisheries variation order since 1999 and MPA regulations since 2005), has protected Gilbert Bay cod and their habitat.

Although the Gilbert Bay MPA protects the local cod population at least until individuals reach sexual maturity, there is concern that fishing activities adjacent to the MPA will become an increasing concern if reproductive success remains at a low level. Large, mature cod are susceptible to fishing pressure because their summer feeding migrations include areas outside the MPA, where fishing activities continue. Currently, smaller fish are at low levels of abundance following several years of poor recruitment. Export of large fish in some instances is viewed as "spillover" and is sometimes considered an indicator of MPA success, but this is not the case for the Gilbert Bay cod population. The large migratory Gilbert Bay cod represent the populations spawning component, which returns to Gilbert Bay each fall to spawn. There is no evidence from tagging of net export of spawners from the bay. Over-harvesting of spawners during periods of poor recruitment would be a poor fishery practice, particularly within the context of an MPA.

In recent years the level of commercial Atlantic cod fishing effort and landings has increased in the vicinity of Gilbert Bay. Maddock and Stead (2008) report increased sentinel fishery catch rates in the vicinity of Gilbert Bay (at Spear Harbour, St. Lewis, and Mary's Harbour) during the past three years. Catch rates have increased from 1-3 fish per net to 5-6 fish per net, a modest increase but perhaps reflective of the potential output from a small local population such as the Gilbert Bay cod population. Tagged Gilbert Bay cod have been caught at each of these locations in the past, demonstrating that some Gilbert Bay cod move to these areas. The size of fish caught is consistent with the size of fish absent from the Shinneys during summer, but is also a product of gear

selectivity. There is also limited information regarding the abundance of northern cod, and what proportion of the commercial catch in the area of Gilbert Bay is from that population. If the abundance and thus catch rates of northern cod is high, then the impact upon Gilbert Bay cod should be reduced.

SUMMARY

Our monitoring data based on 5 indicators reflect changes in the Gilbert Bay cod population demographics, including juvenile cod recruitment, trends in abundance, and catch rates. Our monitoring suggests an overall decrease in abundance of Gilbert Bay cod during the time frame of our monitoring. Recruitment has been highly variable and low during several years of monitoring. Behavioural changes that develop with ontogeny enable size selective fishing mortality on large Gilbert Bay cod which leave the MPA during summer and fall. Monitoring data suggests that the biomass of commercial size fish has decreased substantially during the past two years. Habitat requirements of the population include areas outside the MPA. Fishing activity in areas surrounding the MPA has increased in recent years; however, the MPA has provided protection to important spawning and nursery habitats, as well as some adult foraging/feeding habitats.

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Table 1. Summary of angling data collected in The Shinneys, within Gilbert Bay during spring and summer sampling periods, from 1998 until 2008.

Year	Sampling period	Mean CPUE	Rod hrs	Fish caught
1998	June 1-10	5.80	88	439
1999	May 20 -June 2	3.44	168	599
2000	June 10-22	3.11	148	447
2001	May 29 - June 7	3.40	84	273
2002	June 11 - 19	4.16	162	678
2003	June 4 - 10	2.37	128	300
2004	June 1-8	4.37	126	511
2005	June 1-19	3.29	222	675
2006	June 1-10	3.16	224	573
2007	June 1-10	2.06	224	434
2008	June 2-12	2.15	284	418
2009	June 2-11	2.53	274	491
1998	July 27-August 3	7.24	23	163
1999	August 2-12	10.93	30	314
2000				
2001	July 30 - August 5	5.32	39	193
2002	July 31 - August 6	12.54	51	424
2003				
2004	August 1-7	7.48	54	382
2005	August 2- 8	4.72	63	329
2006	July 31 - August 5	8.03	50	324
2007	July 31- August 7	3.70	73	290
2008	August 2-11	2.54	206	343
2009	August 2-10	5.43	191	614

Table 2. Commercial Atlantic cod catches reported by Department of Fisheries and Oceans dockside monitoring program, at locations where tagged Gilbert Bay cod have been caught and reported by commercial fishermen. Fishing areas include headland areas between Salmon Point (N 52 37 44, W 055 44 51) in the north, to Cape spear (N 52 26 35, W 055 37 38) to the south, and all of Alexis Bay. The northern cod fishery was closed from 2003-2005.

Year	Fishermen with reported landings	Total catch (kg) Round Weight	Individual Quota (kg)	% quota caught by active fishers
1998	12	8,135	1125	60
1999	11	12,057	1082	99
2000	3	613	3810	5
2001	2	928	3810	12
2002	9	5740	3810	17
2006	10	6,598	1361	48
2007	19	17,672	1134	82
2008	23	17,631	1474	67
2009	Not Available	14,385	1700	Not Available

Table 3. Recapture information for 211 Atlantic cod caught in Gilbert Bay from 1998 to 2008. Values indicate percentage of Atlantic cod recaptured at the original tagging location. The numbers of recaptures are indicated bellow the percentage. Each year, Atlantic cod were tagged in spring (late May to early June) and summer (Early august) during field research trips that lasted from 10 to 14 days.

Tag Season	Recapture Season	Same trip	Same year	1 year later	2 years later	3 years later	4 years later	5 years later	6 years later	8 years later	Total
Spring	Spring	92.6 *25 of 27*		56.7 *17 of 30*	87.5 *21 of 24*	40.0 *6 of 15*	50.0 *6 of 12*	50.0 *2 of 4*	50.0 *2 of 4*	50.0 *1 of 2*	**68.0** ***80 of 118***
Summer	Summer	100 *6 of 6*		87.5 *7 of 8*	50.0 *1 of 2*	-- *0 of 1*					**80.0** ***12 of 15***
Summer	Spring			50.0 *2 of 4*	33.3 *2 of 6*	100 *3 of 3*	-- *0 of 1*	100 *1 of 1*			**58.8** ***10 of 17***
Spring	Summer		77.8 *28 of 36*	93.3 *14 of 15*	60.0 *3 of 5*	25.0 *1 of 4*			*0 of 1*		**75.4** ***46 of 61***
Total		**93.6** ***31 of 33***	**77.8** ***28 of 36***	**70.2** ***40 of 57***	**73.0** ***27 of 37***	**43.5** ***10 of 23***	**46.2** ***6 of 13***	**60.0** ***3 of 5***	**40.0** ***2 of 5***	**50.0** ***1 of 2***	

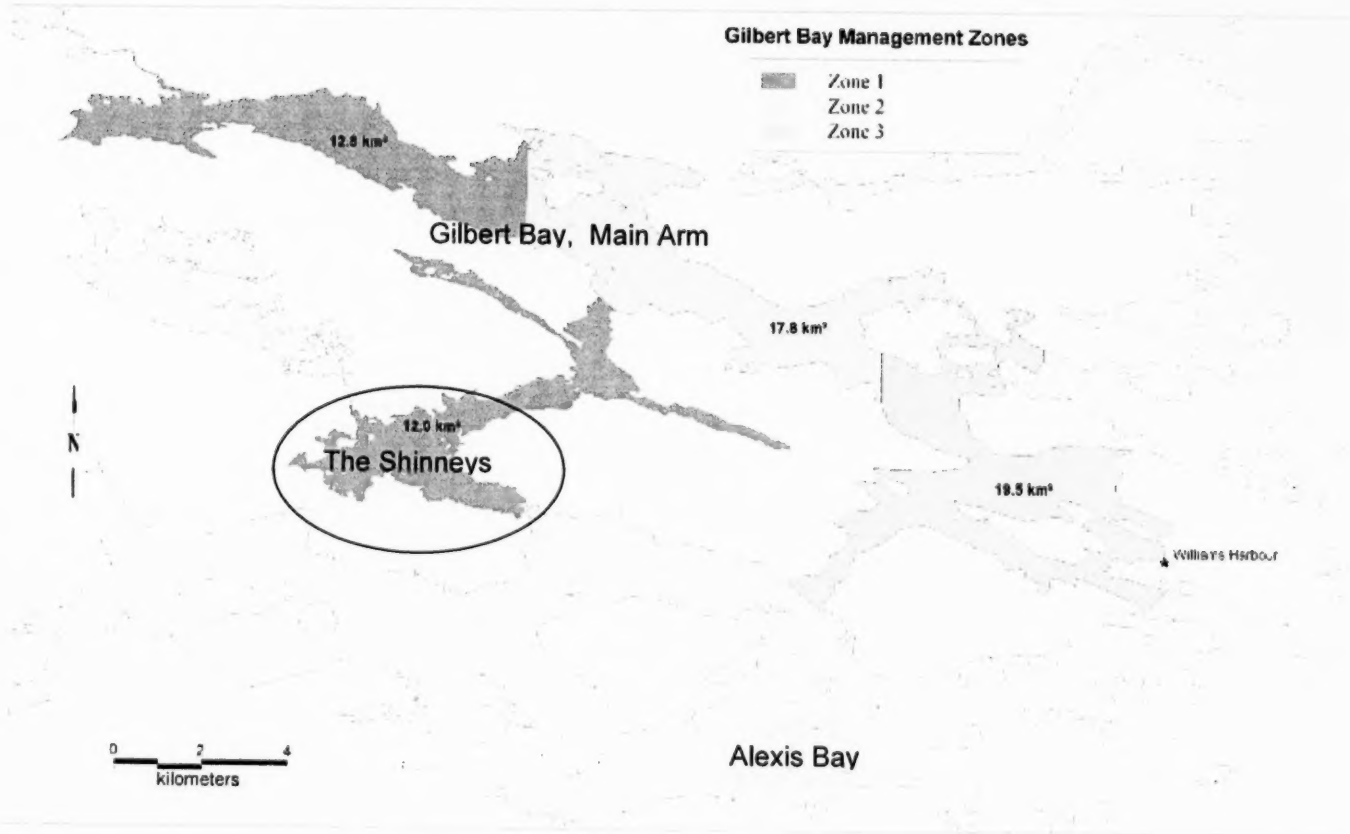
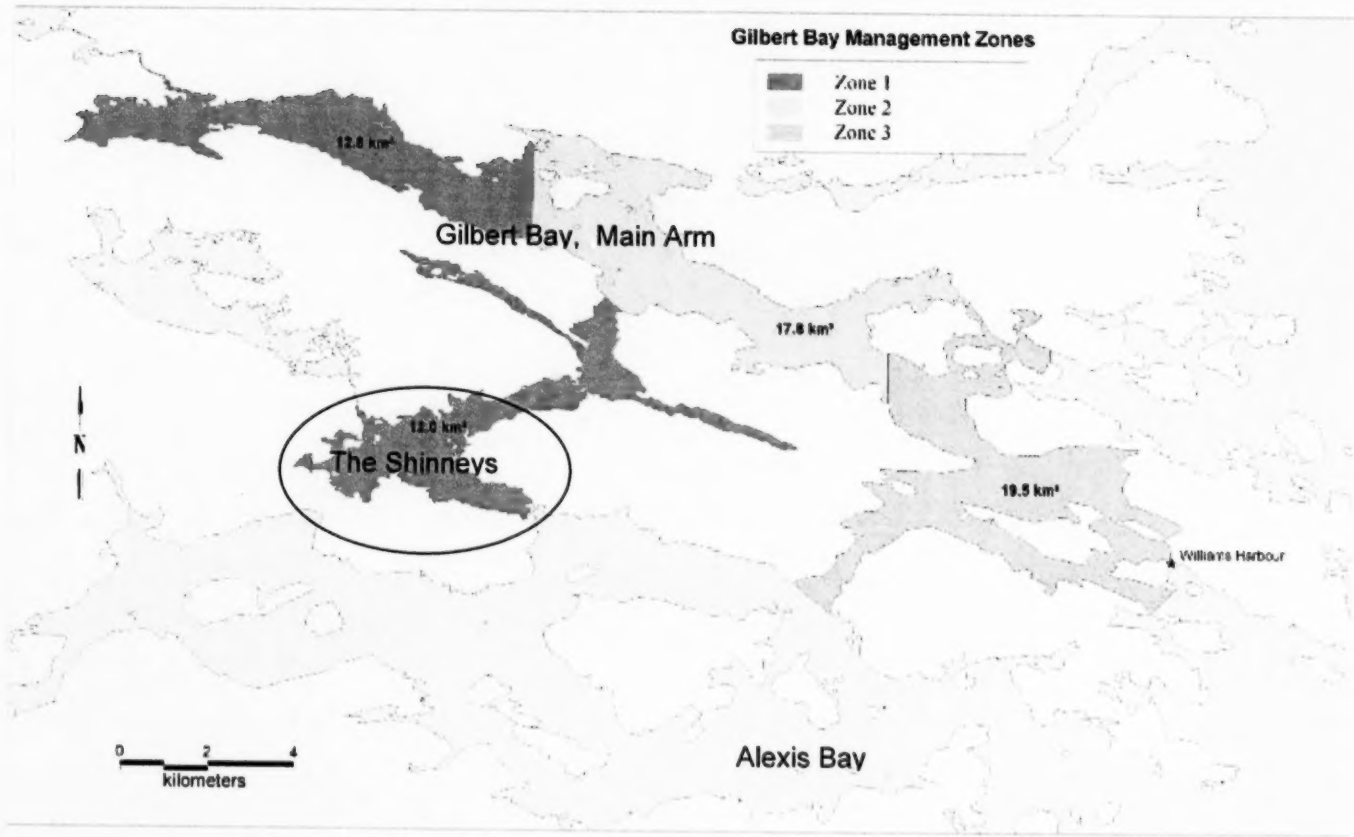


Figure 1. Map of Gilbert Bay Marine Protected Area, and management zones.



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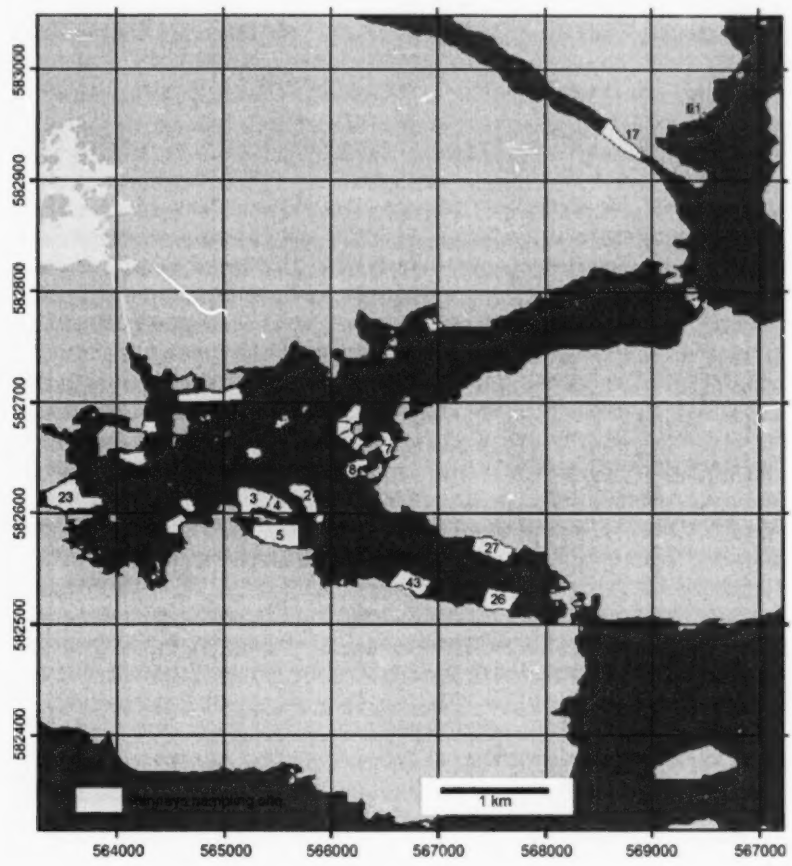

Figure 2. Sampling locations in The Shinneys area, within Gilbert Bay.

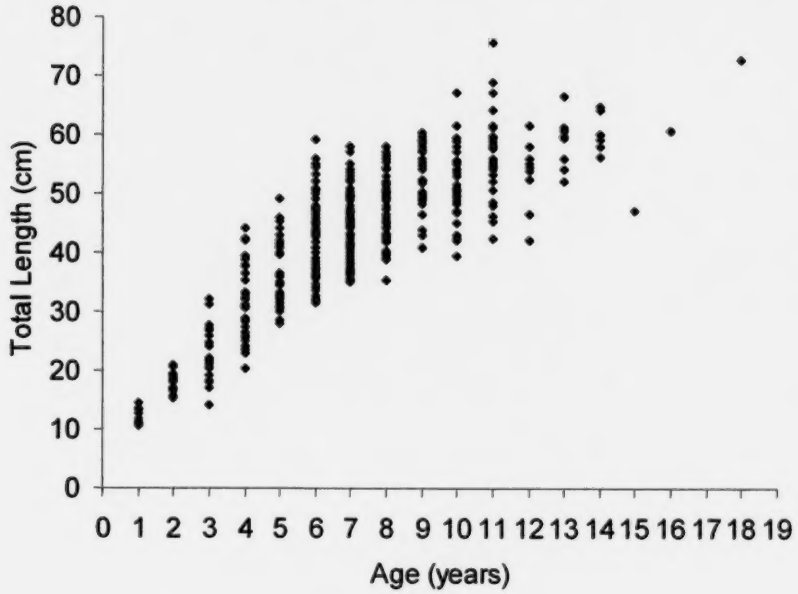

Figure 3. Length at age relationship for Gilbert Bay cod based on 525 otoliths collected between 1998 and 2007.

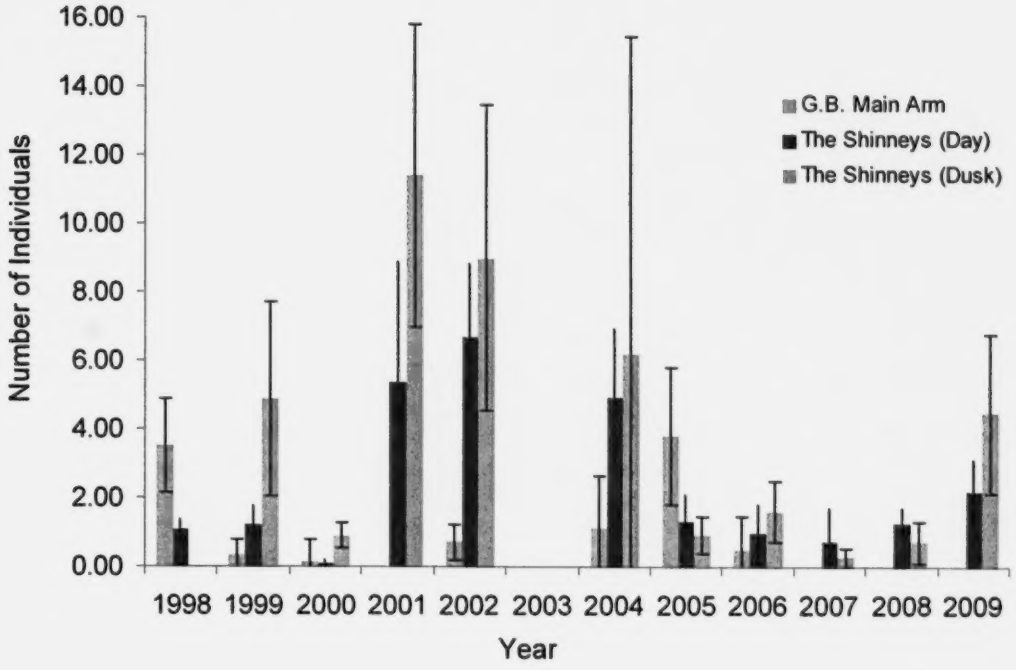

Figure 4. Mean number of age-0 pelagic juvenile cod sampled from the Main Arm of Gilbert Bay (G.B. Main Arm) and from The Shinneys during day and dusk ichthyoplankton tows. 95% confidence intervals are indicated.

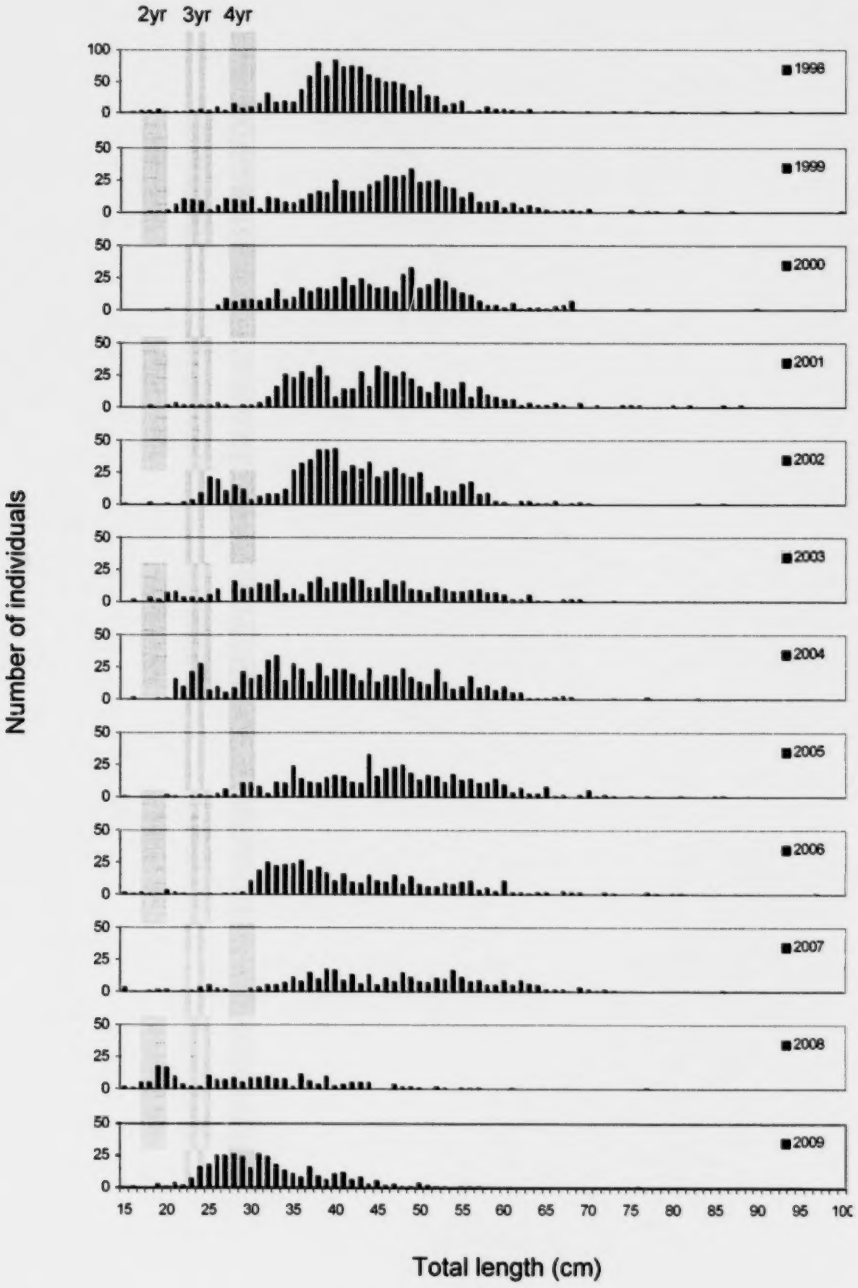

Figure 5. Gilbert Bay cod length Frequency distributions, standardized by mean annual spring sampling effort in The Shinneys, from 1998 (top) to 2009 (Bottom). Approximate fish length corresponding to ages 2-5 years are indicated. Note that the y-axis for 1998 is different than other years due to higher catch rates that year.

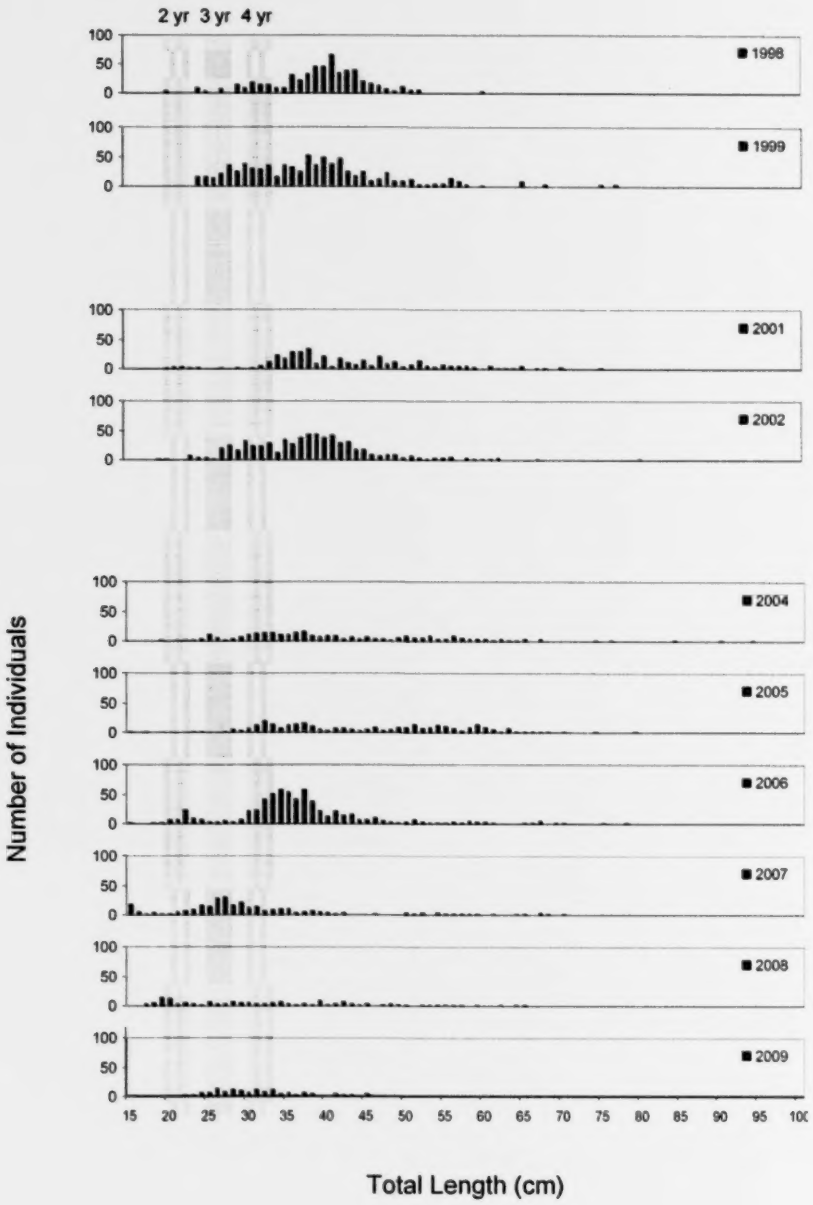

Figure 6. Gilbert Bay cod length Frequency distributions, standardized by mean annual summer sampling effort in The Shinneys, from 1998 (top) to 2009 (Bottom). Approximate fish length corresponding to ages 2-5 years are indicated.

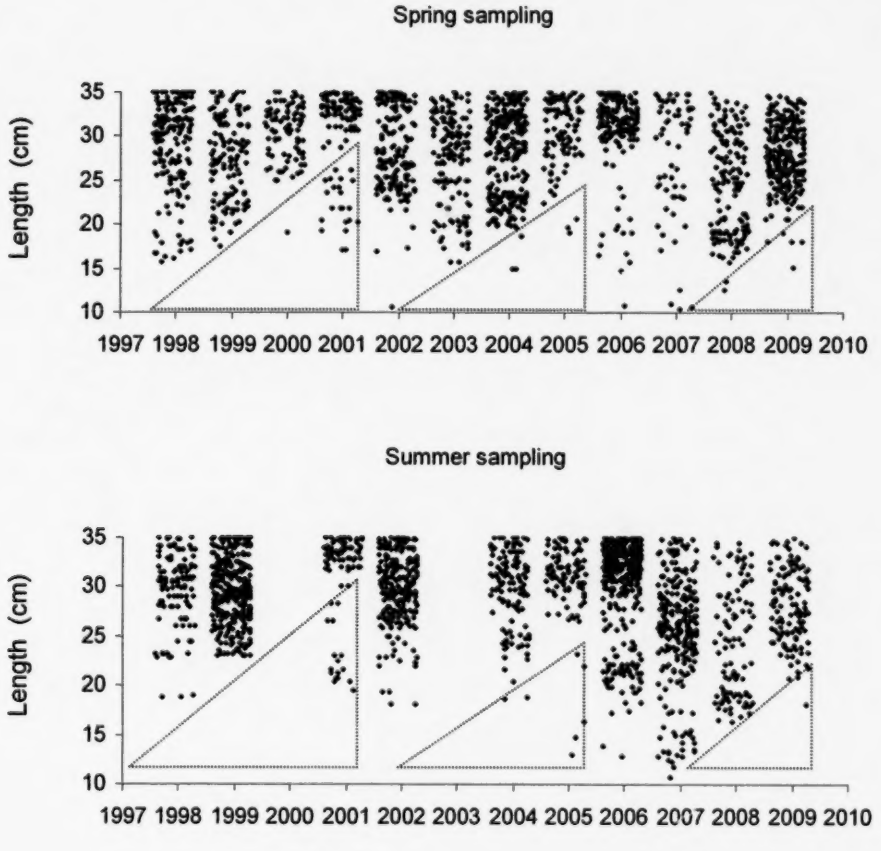

Figure 7. Standardized juvenile Atlantic cod length data sampled in Gilbert Bay (The Shinneys) during spring and summer. No data are available during summer of 2000 and 2003. Similar patters tracking both strong and week cohorts are noticeable in both plots, indicating variable annual recruitment. The area inside the triangles indicates periods of poor recruitment.

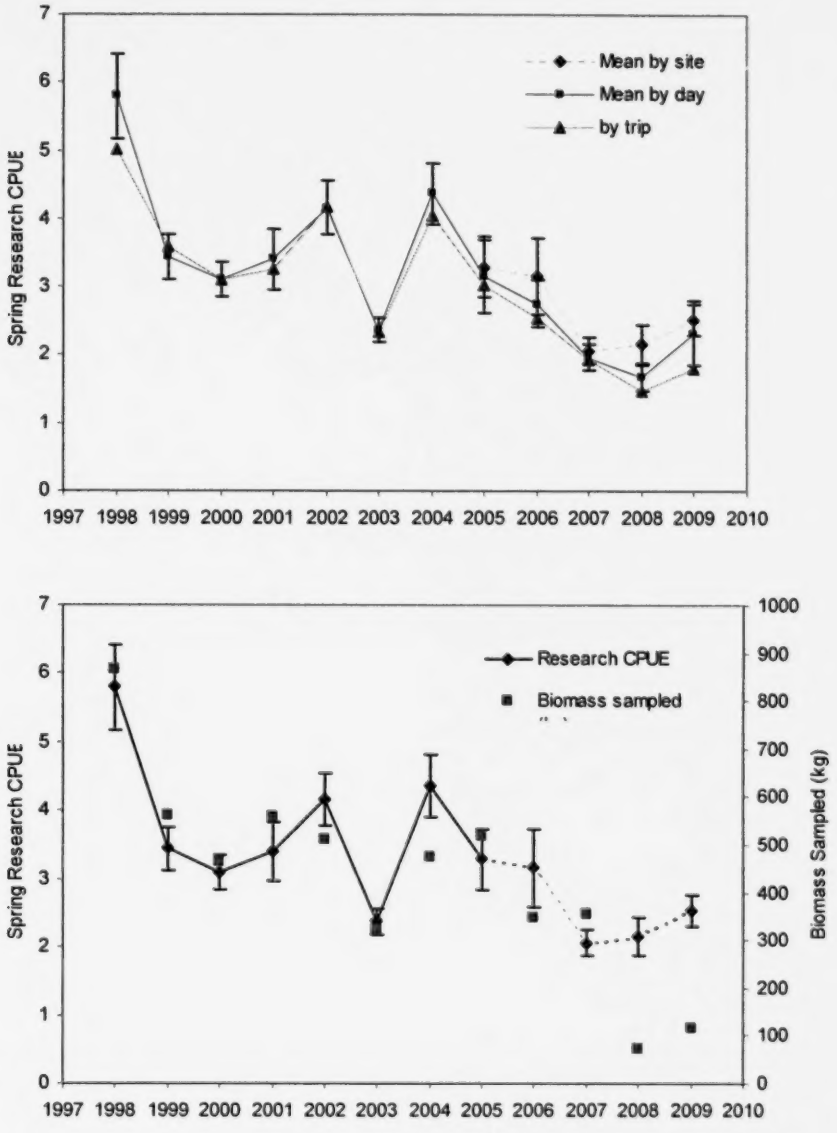

Figure 8. Top panel indicates spring research catch per unit effort (CPUE) data collected at sampling sites in The Shinneys area of Gilbert Bay. Top panel indicates annual research CPUE, as well as, the mean research CPUE and standard error of daily sampling (1998-2009) and sampling by site (2005-2009). Bottom panel indicates CPUE data and the standardized biomass of cod sampled during each spring sampling. CPUE in the bottom panel is based on mean CPUE by day from 1998-2004 and mean CPUE by site from 2005-2009. Lower biomass in relation to CPUE indicates that fewer large fish were sampled.

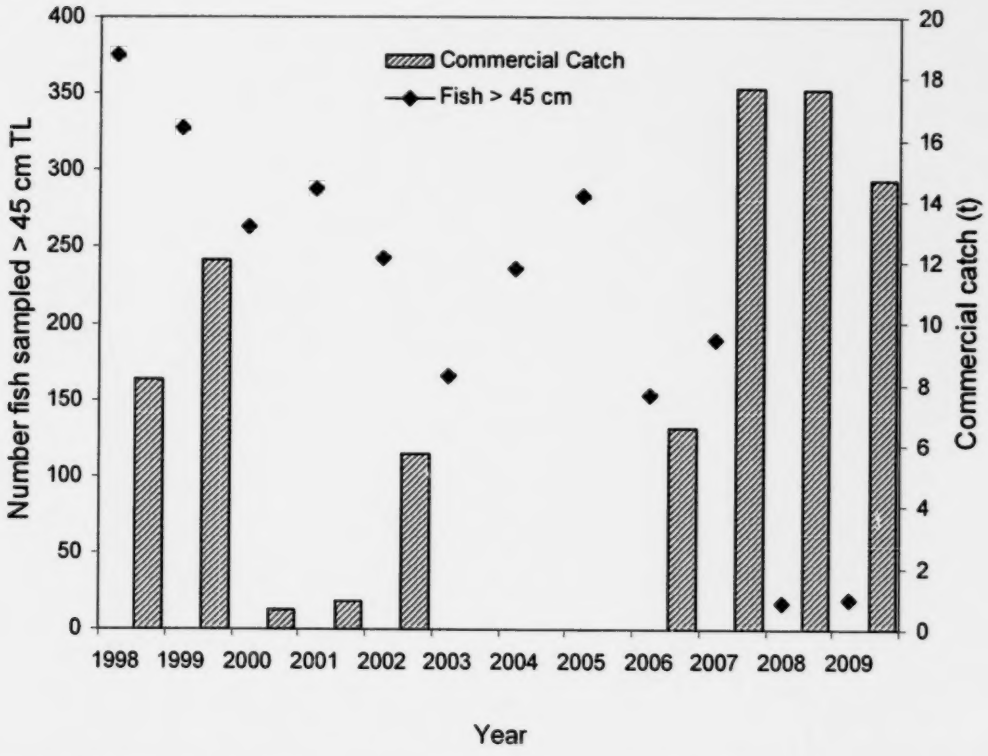

Figure 9. Total standardized catches of Gilbert Bay cod larger than 45 cm TL caught during annual spring research sampling in The Shinneys (primary y axis), and commercial catch data (Secondary y axis). Cod larger than 45 cm were selected because they are caught commercially, see figure XX. Commercial catch data is based on DFO dock side monitoring of catches, from areas where tagged Gilbert Bay cod have been recaptured in the past.

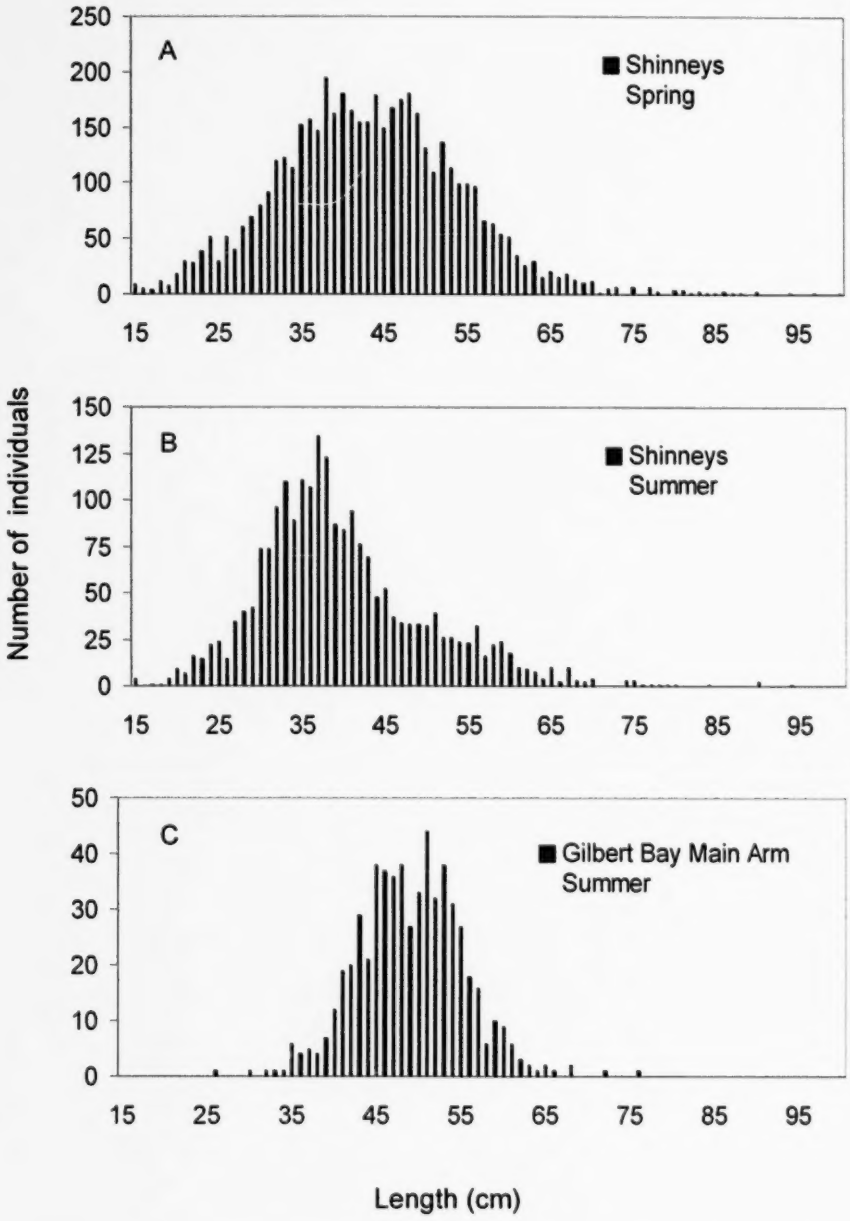

Figure 10. Summary of length frequency data collected in The Shinneys during spring and summer (panels A and B), and from Gilbert Bay's Main Arm (panel C), from 1998 to 2007

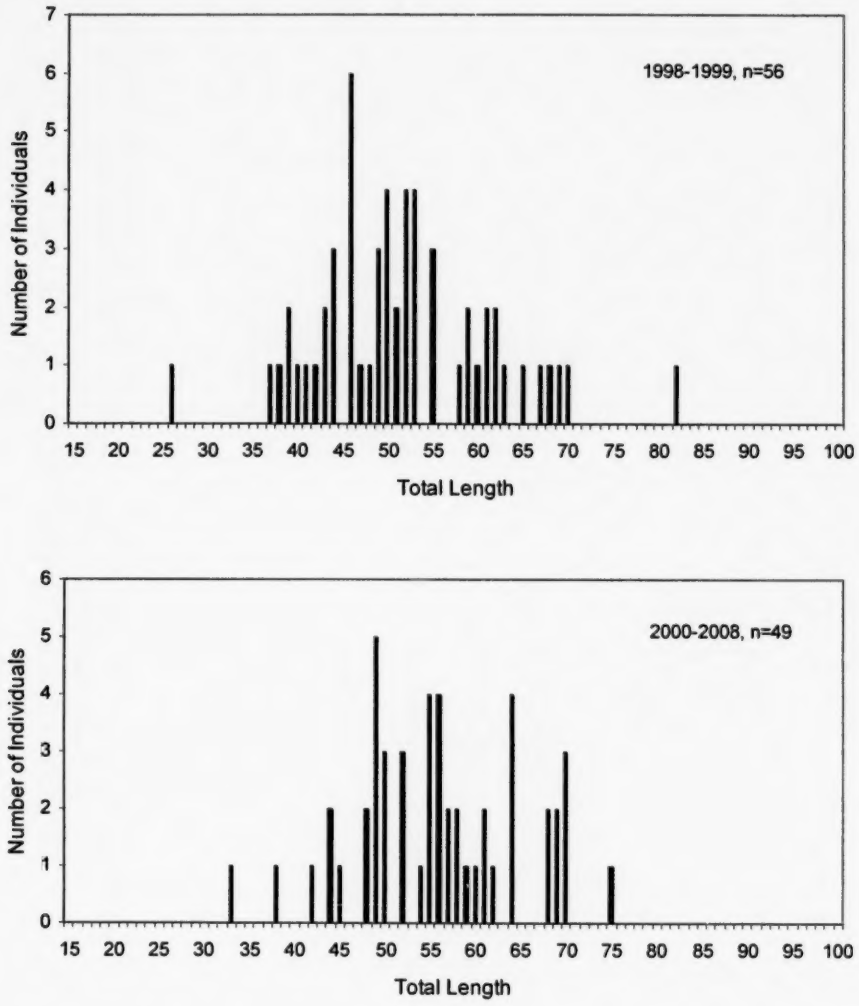

Figure 11. Length Frequency distribution of Gilbert Bay cod tagged during spring sampling in The Shinneys and recaptured during commercial fishing activities. Top panel includes recaptures from within Gilbert Bay, during 1998 and 1999. Bottom panel includes recaptures from outside the MPA during 2000-2008. Commercial recaptures have been reported from areas 10 km north of the MPA and 30 km south of the MPA. Fish growth between tagging and recapture is estimated from the length at age relationship for Gilbert Bay cod, however, in most cases recaptures occurred during the same season or the following year.